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This paper proposes a new approach for developing and understanding reduced manning at the crewing level proposed for DD 21. It is based on the combination of generalized principles from systems engineering, object oriented programming, and symbiotic biological structures in nature. This combination produces a very efficient and survivable integration base for coordinating, controlling, supporting, analyzing, and documenting the overall problem. The approach is the result of a personal attempt to reason through and make sense out of the Coast Guards' last twenty years of reduced manning operations. Much of the information that could be used from this history has never been documented or studied because it doesn't fit what the "experts" are saying, and involves many significant factors that can't be directly measured. What is needed, is detailed open minded analysis based on the assumption that reduced manning is much more complicated than first thought, and is very different from anything that industry, the Navy or the Coast Guard have ever done before. This paper provides first step work for bringing together the background information and foundational concepts needed to develop an approach capable of effectively addressing the overall problem.

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Rethinking Reduced Manning Design and Optimization Using a Modified Systems Approach

ABSTRACT

This paper proposes a new approach for developing and understanding reduced manning at the crewing level proposed for the Navy's next destroyer, DD 21. It is based on the combination of generalized principles from systems engineering, object oriented programming, and symbiotic biological structures in nature. This combination produces a very efficient and survivable integration base for coordinating, controlling, supporting, analyzing, and documenting the overall problem. The approach is the result of a personal attempt to reason through and make sense out of the Coast Guard's last twenty years of reduced manning operations. Much of the information that could be used from this history has never been documented or studied because it doesn't fit what the "experts" are saying, and involves many significant factors that can't be directly measured. What is needed, is detailed open-minded analysis based on the assumption that reduced manning is much more complicated than first thought, and is very different from anything that industry, the Navy or the Coast Guard have ever done before. This paper provides first step work for bringing together the background information and foundational concepts needed to develop an approach capable of effectively addressing the overall problem.

INTRODUCTION

Reduced manning has long promised great savings, increased mission effectiveness, and significantly improved working conditions. The Coast Guard has been operating reduced manned ships for 20 years, but has never been able to achieve these results. The Navy is now working to do the same thing, using essentially the same processes that failed to produce results for the Coast Guard. Both have been relying on the use of standard, specialized program and research groups to supervise contractual development of the best ideas that industry and academia have to offer. When evaluated individually, both on and off ship, most of the things this strategy produces look very good. When used together on an actual reduced manned ship, these same good systems, policies, and solutions work together to do significant damage to readiness and personnel retention, and also generate a large number of long-term related maintenance and personnel problems. The driving factors behind this are very difficult to evaluate with standard analysis and would take years to fully verify, but from a big picture look at actual results, it appears to be true.

Definitions and Common Frames of Reference

The first step to working through reduced manning is to define terms and establish common frames of reference. Reduced manning is a very broad term that has commonly been used to describe a large number of initiatives with a wide range of scopes. Reduced manning should be defined as the reduction of shipboard personnel through the use of automation, shore support, and reductions in operational requirements. It should also be split up and categorized in levels. Studies like Smart Ship, and the Coast Guard's Exemplar and Paragon programs, which evaluated reduced manned ideas on standard Medium and High Endurance Cutters, should be classified as minor reduction efforts. The Navy's proposed new destroyer, DD 21, and the

Coast Guard's 140 ft Icebreaking Tugs, *Ida Lewis* and *Juniper* Class Buoy Tenders, and the Coast Guards newest and oldest icebreakers, the *Healy* and *Mackinaw*, should be categorized as major reductions. These categories are necessary because the complexity and critical factor differences between these two levels are significant. What works well for minor reduction often causes disturbing results on a ship with major reduced manning.

What Really Happens on a Reduced Manned Ship

Major reduced manning pushes people and systems to the point where normally insignificant problems take over and drive everything. Addressing a problem in one area usually causes several worse problems in others. The only thing that works is using solutions that solve their primary target problem, and also address two or three other problems somewhere else. The things that drive this are not readily evident in industry and normally crewed ships. Well-defined tasks and large numbers of people naturally dampen them out. On a major level reduced manned ship, tasks can no longer be simply defined, and there are no clear critical paths for any process. Everything is jumbled together into a complex mix of people, systems and requirements. Major reduction also drops crew size down below the point where people can reasonably compensate for integration discontinuities and normal gaps in leadership and support. These problems cancel out the savings that reducing personnel and increasing technology are supposed to produce. They also degrade shipboard life down to a never-ending struggle to meet constantly changing, short-term related requirements that have very little tangible positive effect on primary missions. Long-term related issues, which are the true drivers behind life cycle success, get ignored because they are difficult to measure and do not have immediate deadlines. When this happens, small attention to detail items, which are also very difficult to effectively contract out or assign to shore support personnel, get ignored, build up, and result in an endless stream of casualties and major readiness deficiencies. The true root causes behind these problems are difficult to identify, and often get hidden through conscious omission or honest unawareness. Together, these things take a tremendous toll on job satisfaction, devotion to duty, and retention. They also greatly decrease equipment service life and often require total overhaul or major replacement to correct.

Small ships tend to do better with this than large ones because their Commanding Officers and shore support personnel are generally in better positions to do whatever it takes to make it all work. Successful major category reduced manned ships typically have Commanding Officers who routinely put their careers on the line, and crews who refuse to let their ship fail no matter what the cost. Other ships, which do not have this level of devotion and sacrifice are often able to maintain an appearance of success, but in actuality are operating on borrowed time which will have to be paid for by the crew that relieves them. Either way, neither of these two modes of operation can be sustained for very long, and both are a costly way to do business.

MODIFIED SYSTEMS APPROACH

Standard practice, incremental design and back end integration produces reduced manning solutions that themselves, each produce new problems that are often worse than the original problem they were intended to correct. No one has been able to close the loop on this process. Breaking out of this cycle will require looking at everything all at once, and then coming up with coordinated solutions that jump ahead of all of the problems and steer everything towards an acceptable final solution.

The following is a generalized approach for developing up front, innovative integration concepts for complex system problems. It was derived out of the authors multidisciplined experience and nine years of working out complicated people-system-organization problems on 50 year old, minimally supported, minimally manned, mature class Coast Guard Cutters.

1. Derive everything down into abstract definitions and core concepts that can be compared and evaluated together.
2. Study and address the most difficult parts of the problem first, in the actual environment that the

problem operates in. Focus on common factors and dynamic interactions.

3. Look for natural solution patterns that are evidenced in the problem itself. Natural solution patterns are characterized by:
   (a) Strategic use of common factors that eliminate unnecessary redundancy.
   (b) Strategic use of dynamic interactions to improve overall system performance.
   (c) Mutually beneficial, symbiotic like integration that provides for efficiency, robust performance, and survivability. Symbiotic integration is characterized by solution pieces that as a natural byproduct of their primary function perform vital functions for other parts of the structure, and also naturally contribute to overall system stability.
4. Define an integration structure and simple measures that will work well for the whole system, that strategically uses common factors and dynamic interactions as an integral part of the design.
5. Break the problem up into modular pieces, according to natural divisions, that will work well with the predefined integration structure. This greatly simplifies detailed design and future modification and maintenance.
6. Develop integration tools and overall concept guidance for the groups and specialists who will be doing detailed, concurrent development of the individual pieces.
7. Modify and reuse existing work where possible using the integration tools.
8. Use traditional theory and specialized expertise to guide final development of modularized pieces.
9. As modularized pieces are finished, use the integration structure to put them together into a steadily growing and maturing, easy to maintain and modify total integrated solution.

Abstract Design Principles

The above approach is an abstract compilation of concepts from systems engineering, object oriented programming, and symbiotic design that requires a multidisciplined, generalized view of understanding to apply.

Systems Engineering and Simple Measures

Systems approaches are needed when designs get pushed to the point where component interactions and interface problems become the most significant part of the problem. Systems engineering does not replace traditional, area specific step by step analysis and design. It works with it by providing an integration structure for coordinating everything together into a well planned, optimized final solution. The key to a systems approach is identifying the most critical factors and then using them to develop simple measures. These measures are then used to guide and coordinate subsystem design and analysis. For reduced manning the most critical factors are:

- Information, control functions, personnel actions, and system component interdependence related to auxiliary system wiring, piping, ventilation, and compartmentation
- Human performance dynamics related to crew attitudes, perceptions, performance and retention

Object Oriented Programming

Object oriented concepts are usually thought of in the context of software development, but if defined in an abstract way could be applied to shipboard systems and organization. Object oriented design provides for reuse of code, simplifies integration and future modification, and allows programmers to do complex things through the interactions of separate, distinct structures.

Symbiotic Natural Design

Principles from both systems engineering and object oriented programming are common in nature. Natural systems use complex combinations of subsystems and components that perfectly fit the overall end design, all work together to minimize problems, and naturally drive everything towards a stabilized optimal solution. The reduced manning solution components outlined in this paper were patterned after these principles.

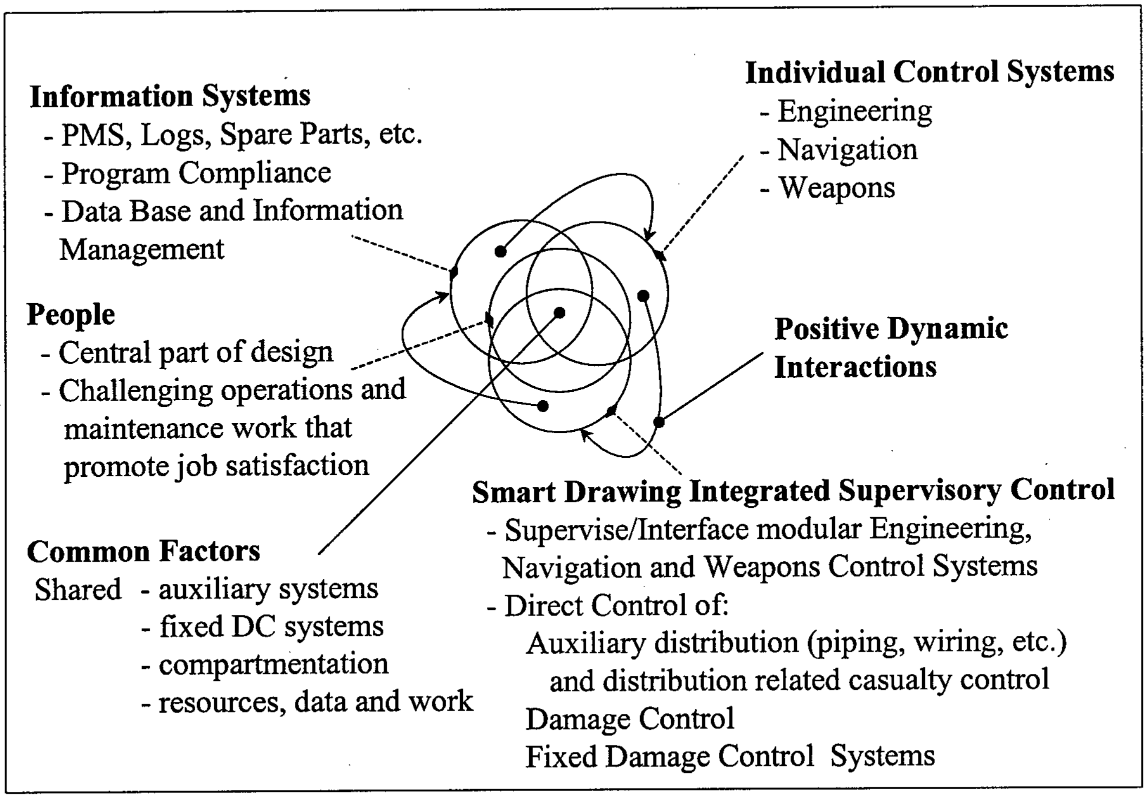


Figure 1. Total Ship System Structure

Figure 1 provides an overall conceptual description that illustrates how the concepts outlined by this paper fit together into a symbiotic solution that naturally fits the problem. The structure depicted by the intersecting circles illustrates the interactive, overlapping, nonlinear nature of reduced manned systems, tasks, and organization. System interactions and the way that people behave in a reduced manned environment, make reduced manning act nonlinear. Standard design and problem solving approaches use linearized solution methods that break problems up into small pieces that are individually solved and then put back together to determine the final solution. Breaking up a nonlinear problem totally changes the way the problem behaves. Nonlinear problems require looking at everything all at once and then jumping ahead to the final solution. Once the end structure and problem piece interrelationships are defined, the problem can then be broken up and worked either backwards from the end, or forwards to the predefined solution, using a coordinated combination of linearized methods.

MANNING LEVELS AND REDUCED MANNED DAMAGE CONTROL

Damage control is the largest single condition manning load and is the most difficult evolution to deal with in terms of automation, information management, system design and arrangement, and personnel operations. Casualty control is a close second, has a lot of common factors with damage control, and for combat and major damage often has to be done in conjunction with damage control. Once the automation concept and corresponding level of personnel required for damage and casualty control is established, then everything else should be designed around optimal use of these systems and the corresponding number of people needed to operate them. Doing this will require working everything that relates to damage and casualty control into a closely coordinated, information intensive solution that fits the way shipboard

personnel work and think. The current state of most of the things that go into this are the result of years of separate evolution in response to a multitude of dissimilar and often conflicting requirements. Integrating them will require going back and reconciling the elementary assumptions they were originally based on.

Damage Control Categories

For reduced manning, damage and casualty control should be categorized into two levels.

Auxiliary Ship Damage Control

For most Coast Guard and Navy Auxiliary ships, automated damage and casualty control should be designed around single point compartment damage and engineering casualties that can be taken care of by a few well-trained personnel with effective communications and accurate pinpoint information. The key to this level is integrating information systems and control together with interior communication and remote monitoring. This would provide a sufficient level of survivability for maintaining operations through most at sea emergencies. Major damage would require ceasing operations and then focusing ship resources on containing damage until off ship assistance arrives.

Combatant Ship Damage Control

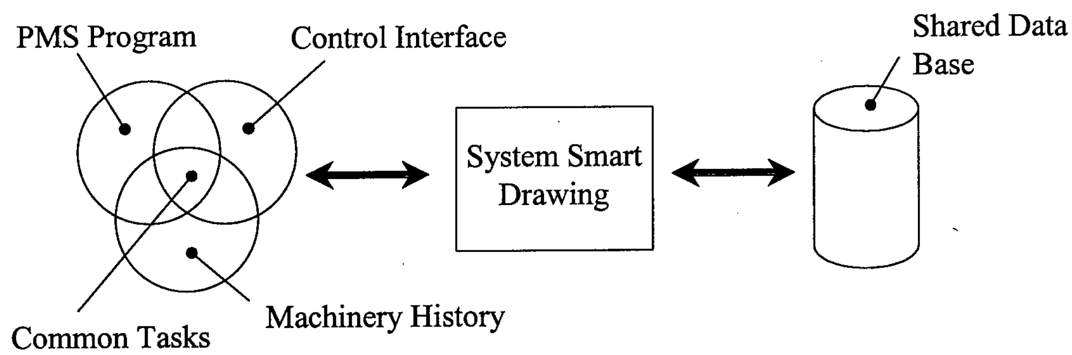
Reduced manned damage and casualty control on combatant ships should be designed around continuing operations despite major damage to multiple compartments and large numbers of vital system components. The key to combatant level automation is expanding the integrated systems developed for auxiliary ship reduced manning to include electrical distribution, piping, and ventilation system design and control.

INTEGRATING AUXILIARY DISTRIBUTION, CONTROL AND INFORMATION MANAGEMENT

For the purpose of this paper, auxiliary distribution is being used as a general term for all of the system component, personnel operation, interior communication and compartmentation considerations that go into system restoration, compartment isolation, stopping cascading casualties and progressive damage, and coordinating use of surviving system and personnel resources. Auxiliary distribution is the most technically difficult part of reduced manning. If you accurately define the damage and casualty control problem and then develop an integrated supervisory control and information management solution to deal with it, you get an open architectured, easy to operate and maintain integration structure for almost everything else. This includes readiness, procurement, administrative program compliance, Risk Centered Maintenance, logs, maintenance history, spare parts management, Hazmat and EPA requirements, safety, training administration, configuration management, and control of weapons, engineering, and navigation system auxiliaries and vital systems.

Classifying Damage Control as a Topology Problem

If automated damage control and casualty control were classified as topology problems, most of the complications that the Coast Guard and Navy are now experiencing in this area would disappear. From a topology point of view, pipes, wires, vents, and compartmentation are all the same thing and can all be modeled together as large networks of interconnected components that provide service paths between sources and loads. Many of the analysis and control programs being developed for reduced manning are built around industry derived first principles based analysis, which centers on calculation of flows, pressures, losses, and other efficiency related performance measures. This doesn't work well for tracing out casualty effects that cross from one system to another. Because Navy systems use high margins of reserve, first principles based performance analysis isn't the primary concern; it's also relatively slow compared to other types of analysis. Industry uses first principles based analysis and control because their systems operate on low margins of reserve where small losses are critical. Naval



Applications:

- Defined by natural work
- Common tasks and data collection performed in background
- Data sharing coordinated by smart drawing interface

Smart Drawings:

- Standard user interface
- Defines trace logic
- Changing drawing updates data links and trace logic

Data Base:

- Standardized data structures
- Defined by system components

Figure 2. Smart Drawing Integrated Supervisory Control and Integrated Information Management

systems can sustain relatively large losses and still function. The critical thing in shipboard analysis and control is dealing with single component failures and personnel errors that cascade through the complicated networks of interconnected system services, and then result in major loss of primary mission capability. If topology analysis is used, first principles analysis could be added on as a secondary function. Adding topology analysis on to first principles systems is difficult and problematic.

Power Utility Distribution System Information Management and Control

The information and control system development proposed by this paper is based on concepts used in Virginia Tech's Distribution Engineering Workstation software, DEW (Broadwater 1991 and 1994). DEW is an integrated design, analysis, management, and control software package developed for power utility electrical distribution grids. Power utilities divide their systems into generation, transmission, and distribution. Distribution is the part of the system that starts at a substation and then branches out into the service area. Transmission is the part of the system that interconnects generator plants and substations. Generation and transmission are controlled together through a complex mix of multi-layered low margin, nonlinear, first principles based analysis and control programs. Distribution is controlled separately, and centers on topology based optimal service and restoration path configuration. Analysis and optimization are based on component connectivity, load priorities and capacity. Most of the power utility programs that have been looked at by the Navy were designed for generation and transmission, which does not fit the shipboard problem. Topology based distribution analysis does.

Smart Drawings

DEW is designed around the use of computerized system smart drawings that are made up of graphically displayed linked objects. The drawings look like standard automation system displays but are much more powerful. The drawings define restoration and reliability trace logic and also serve as the interface for linking system related data with control and

design applications. If the distribution system is changed, the only thing that has to be updated is the drawing. The system is structured in three pieces, a graphic user interface, application programmer interface, and a standardized set of data structures. Figure 2 illustrates this concept. This provides for simplified maintenance and concurrent development. Any additional applications developed with these tools fits directly into the overall system without any of the usual integration problems. DEW is sponsored by the Electric Power Research Institute, EPRI, and is currently being used by more than 200 U.S. power utility companies. The topology concepts used in DEW are applicable to any system or personnel operation that can be drawn out on an organizational flow chart, one-line diagram, or isometric diagram like damage control plates and Automated Common Diagrams. DEW's topology processing has also been used to model roads and geographical boundaries associated with remote control of land based systems, which means that topology analysis could also be used to model compartmentation.

Open Architectured Acquisition

The standardized interface and data structure concepts used in DEW could be used to form a new automation acquisition strategy that would break system development into two coordinated pieces. Integration structure, interfaces, and data structures would be defined "in house" by government personnel working with industry in an open, research like prototype contract environment. This work could then be used as performance measures and specifications for detailed concurrent government and industry development of the final system. This would greatly simplify automation system acquisition and would leverage the best aspects of government and industry expertise and capabilities.

Reconciling Damage Control Doctrine and Distribution System Design

Traditional damage control operations that relate to auxiliary distribution focus on securing vital auxiliaries that serve and pass through damaged compartments. Engineering casualty control operations for these same systems focus on keeping vital auxiliaries operational. These goals are in direct conflict with each other. This problem is complicated by the fact that each of the systems involved; chill water, service air, electrical distribution, ventilation, interior communications and others, are designed to meet individually developed engineering service system performance criteria that have evolved seperately over the years. In the 1980's, system complexity increased to the point to where auxiliary distribution fault tolerance and human error became a serious problem on fully manned ships. The Navy responded by putting a lot of research effort into improving fault tolerance, changing training, and improving and standardizing casualty and damage control documentation. Fault tolerance has greatly improved but the core factors behind personnel error have only just started to be addressed.

Current procedures work well for single point system casualties and compartment damage, but not for multiple point casualties and damage that requires coordination between different stations. Multiple point casualties require rapid, pinpoint accurate damage reports and information, and a large number of highly trained personnel. The current best answer for this is to use militarized merchant ship systems and an integrated mix of seperately developed control and information management systems. Using merchant ship automation, which is designed around relatively simple systems and well-defined tasks, will greatly increase the number of complex components, which will in turn greatly increase maintenance requirements. Back end integration of seperately developed information management and analysis programs is problematic and results in low performance, high maintenance systems.

Conceptualizing Auxiliary Distribution Together as a Single System

The solution for this is to think of and treat auxiliary distribution as its own separate system that provides vital services and connectivity for other systems. A workable strategy for this would be to use topology based, system drawing oriented integrated information management and control to centrally control auxiliary distribution,

and distribution related casualty control, damage control, compartmentation and equipment remote monitoring, and internal communications. Standard merchant ship and military automation would be used for navigation, engine room automation, and weapons system control. Coordination between these systems, which usually involves equipment and personnel functions related to auxiliary distribution, would be done through the centralized distribution control and analysis system.

Combining Industry Efficiency and Naval Survivability Design

The goal for reduced manning design is to produce systems that are efficient and survivable. The current strategy for this is to add efficiency based industry design principles directly in with standard naval design to produce systems that are efficient and survivable. This is destined to produce complex, problematic systems that will end up being neither efficient nor survivable because industry and naval design are based on mutually exclusive criteria. Industry design focuses on maximizing profit through the use of economy of scale and small margins of reserve, within some mandated set of minimum reliability and safety constraints. Naval design uses redundancy and large margins of reserve to optimize survivability and mission effectiveness without violating budgetary constraints. The only criterion that works well for both efficiency and survivability is simplicity. The problem with this is that designing simple systems that can perform complex naval ship functions is very difficult.

Vertical Offset Loop Distribution

The distribution system arrangement that best fits with simplicity driven design is the vertical offset loop firemain. Vertical offset loops are good for ships that have good vertical and longitudinal damage control separation, but are not large enough to use horizontal loops. Vertical offset loops have two main horizontal sections that run longitudinally, along the full length of the ship. One is run up high to one side, the other is run down low on the opposite side. The two runs are connected together in several locations by vertical risers that are arranged to coincide with the vertical fire zone arrangement. Isolation valves are installed at each riser connection, and at every point where the horizontal runs pass through the main vertical fire zone bulkheads. This arrangement provides a highly reconfigurable system that decreases the number of required components and works well with modular construction and topology based integrated information management and control. Using this arrangement for piping, wiring, and data would greatly simplify automatic and manual operation, and would also reconcile the current doctrine conflicts between damage and casualty control.

Dual Level Auxiliary Distribution Design for Auxiliary and Combatant Ships

Auxiliary distribution should be designed into two integrated structures. The first structure should be a central data network that does interior communications and data transfer for remote monitoring and control. The second would be a generalized set of looped piping and wiring that delivers services to central distribution points that are arranged according to fire zone separation. Ventilation should be arranged to provide positive and negative damage control ventilation for each zone. Most Coast Guard and Navy Auxiliary vessels would only need the first system. Combatant vessels would need both. The primary design criteria for both of these systems should be damage control and survivability. Efficiency should be second. Using a vertical offset loop arrangement provides for a good mix of all three. Losses in survivability from combining redundant distribution functions, like primary and alternate power feeders and casualty power, into single a system should be offset from gains in reconfiguration ability and simplicity. Using large volume distribution loops that deliver services to common distribution points also provides for more centralized generation and additional economy of scale. Combining this arrangement with topology based information management and control would also provide for implementing things like sparse monitoring and probability based damage estimation. Sparse monitoring combines system modeling with data collection which provides for the use of less sensors and a reliable method of correlating and verifying sensor output.

Survivable Electrical Power

The most critical part of automating damage control on a reduced manned vessel is the availability of survivable electrical power. Throughout modern naval history, major damage has often been followed by extensive loss of power. Part of this has been due to the direct effects of damage and shock, which is an area that the Navy has made significant progress in. Damage control operability still needs to be addressed. Automating reduced manned damage control would require classifying and treating electrical distribution like a damage control system that also supplies service power. Remotely operated valves, doors, and vents need survivable power; and electrical distribution isolation is critical to initial DC response. Isolating power to a damaged compartment results in power loss just like a system fault. Developing a looped distribution power system with solid state automatic bus ties and shore type control algorithms would provide virtually uninterrupted, highly survivable power with reconfiguration switching in 3 to 5 microseconds. Shore type network control could also be used to optimize configuration according to current damage control, casualty control, and mission priority status and requirements.

HUMAN PERFORMANCE DYNAMICS

Human performance dynamics is a nonstandard term that this paper is using for the leadership, work, and system interactive attitude and perception people factors that drive personal sacrifice related performance, motivation, and devotion to duty. Shipboard personnel thrive on challenging jobs that directly contribute to the performance and support of primary missions. Acknowledging this, and then using it as a guide for design and management of reduced manned ships produces astounding results. This is true regardless of ship age, size and the level of support and automation that is being used. The full significance of these factors is generally difficult to appreciate unless people have seen it for themselves. Several articles have appeared in the last year that address these issues and describe the shipboard dynamics behind them (LaBarre 1999), (McCann 1999), and (Sanders 1999).

Human Performance Technology

The Coast Guard is using Human Performance Technology, HPT, as the next place to look for reduced manning solutions. The Coast Guard recently completed a year long reduced manned Buoy Tender System Study, BTSS, that used this approach. The study compiled extensive lessons learned information, and then out of the gathered information and the reduced manned operational experience of the study group, put together some very good first step recommendations for improvement. HPT provided an effective framework for getting the information and people together necessary to produce this work, but using HPT as anything more than a general organizational tool is going to be very difficult. The theory that HPT is based on addresses most of the performance factors evidenced on reduced manned ships, but because reduced manning is so convoluted in comparison to industry, where HPT theory was derived, the principles from HPT will be very difficult to apply. In addition, human performance dynamics, as defined by this paper, are acknowledged by HPT theory, but are considered too difficult and impractical to use (Gilbert 1996) and (Senge 1994).

Simple Measures for Human Performance Dynamics

Looking at reduced manned human performance factors from a design oriented, systems perspective produces an easy to use list of simple measures or questions that work very well at the shipboard level. These questions should be formalized, and then used to evaluate everything that effects reduced manned operations.

- Does this contribute to the crew's perception that leadership cares about them, and understands what they are doing?
- Do the shipboard tasks associated with this have obvious purpose, meaning and value?

- Does the shipboard part of this directly relate to performance and support of the ship's primary missions?
- Does this promote loyalty, ownership, responsibility, and personal development?

Integrating System Design and Human Performance Dynamics

Parts of the solution that do not meet these criteria, and that can not be eliminated or changed should be done in the background by automation and shore support. Automation system interfaces should be designed to specifically focus on core operations and maintenance tasks that from a shipboard perspective are critical to the performance of primary missions. Data for readiness, logistics, program compliance, and budgeting should be collected in the background through the integration network from the interface where the data naturally occurs as part of some mission critical task. Automation and shore support should also be tailored around the crew doing tasks that reinforce a positive work environment. Specialized technical training, maintenance, inspection, and compliance need to be integrated together and designed around the development of a sense of ownership, pride, personal professional development, and being part of a high achievement group. The same thing needs to be done with non-technical training, inspection, and compliance. Many people have done small-scale versions of this on their own at the shipboard level with surprising results. Most of these efforts have gone unnoticed because they usually involve breaking the rules and going against what the "experts" say is the best way to do things.

Reduced Manning Technical Training

A good illustration of how human performance dynamics works is to look at the actual results that standard reduced manning technical training produces. The best technical training, in terms of increased professional expertise and man-hour usage, is using contracted casualty repair and warranty work as an opportunity to let shipboard personnel work with, learn from and then develop ongoing professional relationships with top people in their field. This produces significant improvements in crew morale, ownership, pride, professional expertise, reduced casualties, and an overall increase in system performance that together greatly exceed anything that standard maintenance and training have ever been able to produce. A lot of Engineer Officers and Type Desk Engineers do this, but don't publicize it because they would get into trouble if training and procurement personnel found out what they were doing.

Systems Approach to Reduced Manning Training

A formalized version of this would combine maintenance and technical training together under one command. Personnel would go through scaled down traditional formal schools at different points in their career that focus on general knowledge and principles. System specific training would be spread out, in short segments throughout a person's shore support and shipboard tours. This training would be done through a combination of industry and military short courses, and periodic super tune up visits from top tech reps and maintenance personnel that come to the ship and go through the systems together with the crew. The same top tech reps and master maintenance personnel that do the super tune up visits would also play critical roles in off ship training. Intermixing technical training and maintenance together would greatly improve the effectiveness of both, would give military people more options, and would provide for mentoring and continuity.

Current Reduced Manning Technical Training

The currently accepted plan for training is to use a long string of concurrent pipe-line and standardized off ship formal courses that supposedly fully prepare a person for shipboard technical duty. This looks great on paper but causes more problems than it is worth. The majority of a person's higher level technical skills come from working together with top people on ship with actual systems. Formal schools that mimic this environment produce outstanding results. Courses that are not

structured this way do relatively little for shipboard proficiency and technical expertise.

Pipe-Line Training, Formal Schools, Morale, and Retention

The thing that traditional schools are best for on a reduced manned ship is use as a shipboard atmosphere management tool. Canceling school quotas, which happens a lot, gives the crew the perception that leadership does not care about them, and doesn't understand technical standards and maintenance requirements. If a Commanding Officer is willing to risk sailing without critical people, and understands the human dynamics involved in getting the crew to willingly sacrifice and cover for absent personnel, the crew perceives that the Commanding Officer and their shipmates care about them. Establishing this dynamic is by far the most powerful thing that leadership can do. It has a tremendous impact on morale, loyalty, and retention, and greatly outweighs anything that can be done with automation, support and monetary compensation. It doesn't cost much, and is the single most important factor in making reduced manning work. This dynamic needs to be formally acknowledged and then worked into the organizational structure so that Commanding Officers on reduced manned ships can take care of their people without having to sacrifice their own careers.

CONCLUSION

This paper defines terms, establishes some common frames of reference, and then outlines a modified systems approach specifically tailored for reduced manning. The key to this approach is identifying the most difficult and critical parts of the problem, and then using them to develop simple measures that can be used to guide and coordinate the overall solution. For reduced manning, the most difficult part is dealing with all of the complex, interactive and often conflicting doctrine, information management, control, and design aspects related to auxiliary distribution. Conceptualizing all of the different wiring, piping, ventilation, data, and interior communication distribution that runs throughout a ship together and then treating it as its own separate system greatly simplifies the overall reduced manning problem. It also opens up the possibility of applying a large number of new technologies and integration concepts that are not currently being considered. The most critical part of reduced manning are the subtle people, system, and organizational dynamic interactions that drive personal sacrifice related motivation, performance, and devotion to duty. From a multidisciplined, big picture point of view, incremental, stove-piped design and problem solving appears to be producing divergent solutions that will severely damage the Coast Guard's and Navy's infrastructure. Correcting this will require jumping ahead of the problem and creating reduced manning specific, coordinated systems measurement, analysis and design approaches that strategically use common factors and dynamic interactions. Reduced manning is pushing the Coast Guard and Navy to a system design level that no one has ever done before. If the Coast Guard and Navy recognize this and take appropriate steps to address the unique problems involved, then reduced manning will bring the Coast Guard, Navy, and U.S. Industry into a new era of integrated system design, measurement and control.

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